Physical training of school children with spastic cerebral palsy: effects on daily activity, fat mass and fitness.

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Physical training of school children with spastic cerebral palsy: effects on daily activity, fat mass and fitness

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Effects of two 9-month sports programmes (four or two sessions per week) on level of daily physical activity (PA), fat mass (FM), and physical fitness were assessed in children with spastic cerebral palsy (CP; n = 20, 9.2 ± 1.4 yr), randomly assigned to an experimental and control group after matching. Four sessions per week tended to increase PA ratio (24-h energy expenditure/sleeping (resting) energy expenditure) after 9 months from 1.34 ± 0.25 to 1.55 ± 0.18 (P = 0.07; not different versus controls). FM increased continuously in the control group (after 9 months + 1.1 ± 1.6 kg, P < 0.05), whereas the experimental groups showed no changes. Training (respectively four and two sessions) increased peak aerobic power 35% (P < 0.01; P < 0.05 versus controls) and 21% (P < 0.01; P = 0.17 versus controls). Results also suggest that training has a favourable effect on isokinetic muscle strength. No training-related effects were found on anaerobic power. It was concluded that although aerobic training has a limited effect on PA in children with CP, it may prevent deterioration in body composition and muscle strength. Furthermore, training has a favourable effect on peak aerobic power.

Körperliches Training zerebralparetischer Schulkinder: Auswirkungen auf tägliches Aktivitätsniveau, Körperfettanteil und Fitness

Die Auswirkungen von zwei 9monatigen Sportprogrammen (mit 4 bzw. 2 Sitzungen pro Woche) auf das Niveau der täglichen physischen Aktivität (PA), den Körperfettanteil („fat mass" – FM) und die körperliche Leistungsfähigkeit wurden an Kindern mit spastischer Zerebralparese (CP; n = 20, 9,2 ± 1,4 J.) untersucht, die nach erfolgter Parallelisierung randomisiert einer Versuchs- bzw. einer Kontrollgruppe zugewiesen wurden. Bei wöchentlich 4 Sitzungen stieg der PA-Quotient (24-Stunden-Energieurnsatz / Schlaf- bzw. Ruheenergieumsatz) nach 9 Monaten von 1,34 ± 0,25 auf 1,55 ± 0,18 (p = 0,07; kein Unterschied zur Kontrollgruppe). In der Kontrollgruppe stieg der FM kontinuierlich an (nach 9 Monaten + 1,1 ± 1,6 kg, p < 0,05), während sich in der Versuchsgruppe keine Veränderungen zeigten. Durch das Training (4 bzw. 2 Sitzungen) erhöhte sich die maximale Sauerstoffkapazität um 35 % (p < 0,01; p < 0,05 versus Kontrollgruppe) bzw. 21 % (p < 0,01; p = 0,17 versus Kontrollgruppe). Auch lassen die Ergebnisse darauf schließen, daß das Training sich günstig auf die isokinetische Muskelkraft auswirkt. Keine Trainingseffekte fanden sich hinsichtlich der anaeroben Kapazität. Es wird gefolgert, daß ein aerobes Training zwar nur begrenzte Auswirkungen auf das PA-Niveau zerebralparetischer Kinder hat, daß es jedoch einer Verschlechterung von Body composition und Muskelkraft entgegenwirken kann. Des weiteren wirkt sich ein Training günstig auf die maximale Sauerstoffkapazität aus.

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Entraînement physique en milieu scolaire d'enfants présentant un handicap moteur cérébral spastique: effets sur l'activité quotidienne, la masse grasse et l'adéquation de l'état physique

Les effets de deux programmes sportifs de 9 mois (quatre ou deux séances par semaine) sur l'activité physique quotidienne, la masse grasse et l'adéquation de l'état physique ont été évalués chez des enfants présentant un handicap moteur cérébral (HMC) spastique (n = 20; 9,2 ± 1,4 ans) répartis par randomisation en deux groupes, l'un témoin, l'autre expérimental, après appariement. Quatre séances par semaine ont eu tendance à accroître le rapport d'activité physique (rapport dépense d'énergie sur 24h/dépense d'énergie pendant le sommeil ou le repos), au bout de 9 mois de 1,34 ± 0,25 à 1,55 ± 0,18 (p = 0,07; pas de différence par rapport aux témoins). La masse grasse a continuellement augmenté dans le groupe témoin (+ 1,1 ± 1,6 kg au bout de 9 mois; p < 0,05), mais n'a pas varié dans le groupe expérimental. L'entraînement a augmenté la puissance maximale aérobie de 35% après quatre séances (p < 0,01; p < 0,05 par rapport aux témoins) et de 21% après deux séances (p < 0,01; p < 0,17 par rapport aux témoins). Les résultats suggèrent également que l'entraînement exerce un effet favorable sur la force des muscles isocinétiques, mais qu'il ne modifie pas la puissance aérobie. En conclusion, l'entraînement aérobie, bien qu'ayant un effet limité sur l'activité physique de l'enfant atteint d'un HMC spastique, peut prévenir la détérioration de la composition de l'organisme et de la force musculaire. De plus, l'entraînement exerce un effet favorable sur la puissance maximale aérobie.

La educación física de los niños con parálisis cerebral espástica: actividad diaria, masa adiposa y estado físico

Se evaluaron los efectos de 9 meses de programas deportivos (4 o 2 sesiones semanales) sobre el nivel de actividad física diaria (AF), de masa adiposa (MA) y de estado físico de niños con parálisis cerebral espástica (PC; n = 20, 9,2 ± 1,4 años), asignados al azar a un grupo experimental y a otro de control después de haberlos combinado. En el caso de cuatro sesiones semanales la proporción de AF (24 hr de consumo de energía/consumo de energía durante el sueño-descanso) tendía a variar después de 9 meses de 1.34 ± 0.25 a 1.55 ± 0.18 (p = 0.07; sin diferencia en la comparación con los controles). La MA se incrementó continuamente en el grupo de control (después de 9 meses + 1.1 ± 1.6 kg, p < 0.05), mientras que los grupos experimentales no mostraron cambios. El entrenamiento (de 4 y 2 sesiones respectivamente) elevó el tope de capacidad aeróbica en un 35% (p < 0.01; p < 0.05 en comparación con los controles) y en un 21% (p < 0.01; p = 0.17 en comparación con los controles). Los resultados sugieren también que el entrenamiento tiene un efecto favorable sobre la fuerza isocinética muscular. Se detectaron efectos sobre la capacidad anaeróbica no relacionados con el entrenamiento. Se concluyó que aunque el entrenamiento aeróbico tiene un efecto limitado sobre la AF de niños con PC, puede prevenir el deterioro de la composición corporal y de la fuerza muscular. Además, el entrenamiento tiene un efecto favorable sobre el tope de capacidad aeróbica.

Keywords: adiposity, aerobic power, anaerobic power, cerebral palsy, exercise, isokinetic muscle strength

Introduction

Adiposity and distinctly subnormal physical fitness are frequently observed in cerebral palsy (CP) (Phelps, 1951; Eddy *et al.*, 1965; Lundberg *et al.*, 1967; Berg and Isaksson, 1970; Brown, 1975; Bar-Or, 1983; Dresen, 1983; Bandini *et al.*, 1991; Parker *et al.*, 1992; Berg-Emons van den *et al.*, 1996b). Partly, this may be caused by low levels of daily physical activity (PA). In previous studies, it was shown that children with CP are extremely hypoactive compared to their healthy counterparts (Berg-Emons van den *et al.*, 1995, 1996a).

It is attractive to postulate that an adequate therapeutic measure in children with CP is to increase the level of daily PA by special sports programmes, tailored to the residual ability of the child. However, whether and to what extent sports programmes are effective in increasing daily PA in children with CP has not been studied. A number of studies is available on the effects of training on body composition, aerobic power and muscle strength in CP (Lundberg *et al.*, 1967; Berg, 1970; Bar-Or *et al.*, 1976; Dresen, 1983; McCubbin and Shasby, 1985; Rintala and Lyytinen, 1988; Wormgoor and Gierlings, 1989; Fernandez and Pitetti, 1993), but most of them concern heterogeneous and older age groups and training programmes often last for a relatively short period (4–10 weeks). Furthermore, control groups are usually not included. To our knowledge, no studies exist concerning effects of training on anaerobic power in CP.

The aim of the study was to assess whether 9-month, predominantly aerobic, sports programmes (four or two sessions per week) are effective in increasing the level of daily PA in school children with spastic CP and whether this has favourable effects on fat mass (FM), peak aerobic power, anaerobic power, and isokinetic muscle strength. An experimental controlled design was used.

Material and methods

Subjects

Twenty children (11 boys, 9 girls) with spastic CP participated. The children were between 7 and 13 years of age and were day students at the Children's Rehabilitation Centre Franciscusoord in Valkenburg (normal intelligence and mild mental retardation). Nineteen children were Caucasian, one was born in Sri Lanka. The children were classified according to Hagberg (in Olow and Berg, 1970) by a physician at Franciscusoord. When legs and feet were more affected than arms and hands, children were classified as diplegic (n = 16); children with a greater affliction of the upper part of the body than of the lower part, were classified as tetraplegic (n = 4). In two diplegic children, a mixed form of spasticity and ataxia was present. Half of the children was ambulant, the other half wheelchair-bound. The children and their parents were informed of all aspects of the study and written consent was obtained. The study was approved by the Medical Ethics Committees of the University of Limburg and the Cooperating Rehabilitation Centres, Limburg.

Experimental design (see also Fig. 1)

The project lasted 2 years and included two training periods of 9 months. At the beginning of the first year (in September, after the summer holidays), the children were matched pairwise for physical ability, mental function, and if possible, for age, gender and body composition. After matching, the children of each pair were randomly assigned to an experimental group (EXP_{4x}, n = 10) or a control group (CON, n = 10). EXP_{4x} participated in a 9-month training programme, with 45-min exercise sessions four times per week above the normal school and therapy programme, whereas CON had no extra physical training (the school programme included two 45-min gymnastic lessons per week; therapy programmes were based on personal needs and varied from no therapy to more

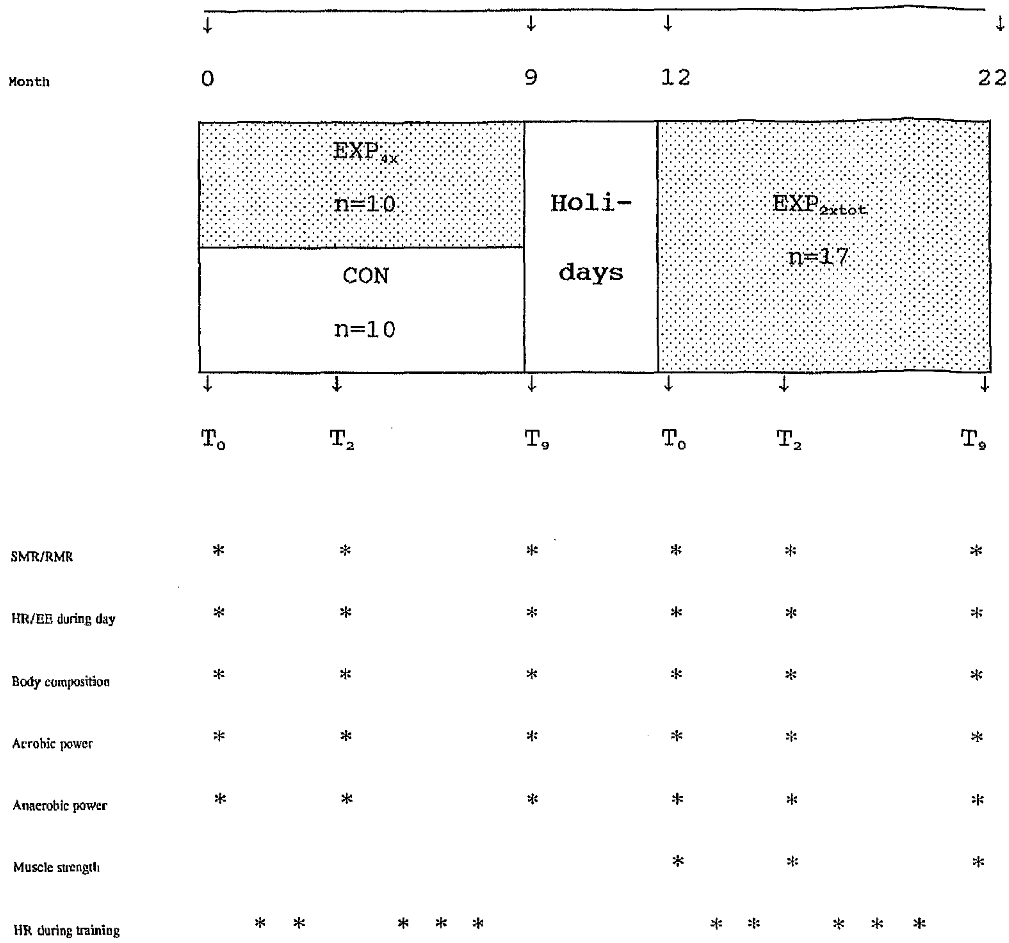


Fig. 1. Schematic presentation of the study design (training periods are shaded).

than 2.5 hours per week). Training activities consisted of predominantly aerobic exercises such as cycling, wheelchair driving, running, swimming, training on a 'flying-saucer', and mat exercises. Heart rate (HR) was measured (Sport Tester PE3000, Polar Electro, Kempele, Finland) randomly during the training sessions to get an impression of the training intensity. Habitual diets of the children were not changed during the study years. Measurements were performed in both EXP_{4x} and CON before the training programme started (T_0, September/October), after EXP_{4x} had trained for 2 months (T_2, December), and after 9 months of training (T_9, June/July).

After the summer holidays (2 months), the children of both EXP_{4x} and CON were given the opportunity to participate in the next training programme, with a practically more feasible training frequency of two times 45 min per week. Eight children of EXP_{4x}, and all children of CON participated (EXP_{2xtot}). Two children of EXP_{4x} left the programme because of lack of motivation and necessity to spend more time on school tasks. The training activities and measurements in the second year were, in general, similar to the design in the first year. For practical reasons, isokinetic strength measurements were not performed in the first study year and swimming was not included as a training activity in the second year.

Anthropometry

Body weight was obtained, while wearing light clothing, on a chair scale (Seca, Germany). Height measurements were taken with subjects standing against a wall, or if unable to stand, while lying on a bed with a wooden T-square or flexible tape. Thickness of 4 skinfolds (biceps, triceps, subscapular, suprailiac) was measured with a Servier Caliper at the non-dominant side of the body. Fat mass (FM) was calculated according to Durnin and Rahaman (1967).

Level of daily PA

Level of daily PA was calculated as the ratio of total energy expenditure (TEE) to sleeping metabolic rate (SMR) or TEE to resting metabolic rate (RMR). In the first year, SMR was measured in children who wanted and were able to stay overnight in a respiration chamber ($n = 12$); in the other children ($n = 8$), RMR was measured by means of a ventilated hood. Because the respiration chambers were not operative during the second year (laboratory moved to a new building), all children had RMR measurements during this period.

The respiration chamber (Schoffelen *et al.*, 1984), an open-circuit indirect calorimeter (14 m^3), was furnished with a bed, chair, table, TV, telephone, intercom and toilet. The chamber was ventilated with fresh air at about 40 l/min and air temperature was maintained at 20°C. Volume of outgoing air was determined by means of a dry gas meter (Schlumberger type G6, Dordrecht, The Netherlands) and gas was analysed with a paramagnetic O_2 analyser (Servomex type OA 184, Crowborough, England) and an infrared CO_2 analyser (Hartman & Braun type URAS 3G, Frankfurt, Germany). An on-line micro-computer controlled the gas sampling system. PA was monitored by means of a radar system, based on the Doppler principle. SMR was calculated according to Weir (1949), over a period in which radar activity was lowest and subjects were asleep.

RMR was determined under standard conditions in a comfortably warm room by an open-circuit ventilated hood system (Oxycon Beta, Mijnhardt, The Netherlands). Children were transported to the university by car and any form of intensive exercise was avoided. Measurements were performed between 7.30 and 9.00 a.m., after having fasted for 12 hours. After a period of 5 min bed rest, RMR was measured during 20 min while the children watched TV or listened to stories (supine position). RMR was calculated according to Weir's formula (1949). In order to assess the difference between SMR and RMR, RMR was also measured in 12 children in the morning after the measurement of SMR (T_9, first study year).

TEE was determined by the heart rate (HR) method, which has been shown to be suitable to predict TEE in groups of children with CP (Berg-Emons van den *et al.*, 1996a). Children were fitted with the HR instrumentation (Sport Tester PE3000, which recorded HR at 1-min intervals) at about 9.00 a.m. and it was worn continuously until they went to bed (in experimental groups HR recording was performed on a training day).

In each child the relation between HR and VO_2 was established under standardized conditions during each measurement period. In the ambulant children ($n = 10$), four calibration points were obtained by simultaneous measurements of HR and VO_2 during sitting, standing, and cycling on an ergometer (Universal Ergostat Fleisch, Metabo, Epalinges, Switzerland) at 30% and 70% of their previously assessed peak aerobic capacity (progressive cycling test). In wheelchair-bound children who were able to cycle (n = 3), three calibration points were obtained: during sitting and cycling at 30% and 70%. Wheelchair-bound children who were not able to cycle (n = 7) were measured during sitting and arm cranking (at 30% of their peak capacity for work with two arms). Arm cranking tests were performed on the Fleisch ergometer with one arm, while the children were sitting in their own wheelchair beside the ergometer. It was impossible to measure HR and VO_2 at higher intensities in the arm cranking group, because when the resistance was increased, the children lowered the cranking speed and no increases in workload, HR and VO_2 were attained. VO_2 was measured using a face mask connected to a Jaeger EOS-sprint analyser (Jaeger Nederland, Breda, The Netherlands) and HR was taken from an ECG monitor. An equilibration period of 2 min was allowed for each activity, followed by a 4-min sampling period. The calibration point for each activity was computed as the mean of the 4 min sampling period for HR and VO_2.

TEE was calculated from HR, according to the 'FLEX' principle (Saris *et al.*, 1982). FLEX HR in the ambulant group was defined as the mean of the highest HR during standing and the lowest HR during cycling. Oxygen uptake during rest was calculated as the mean VO_2 of lying (measured in respiration chamber or by the ventilated hood), sitting and standing. Energy expenditure (EE) over periods of the daytime when HR was ≤ FLEX HR was calculated on the basis of this mean VO_2. When HR was above FLEX HR, EE was derived from the min-by-min recorded HR and the subjects calibration curve obtained on the ergometer. FLEX HR in the wheelchair-bound children who were able to cycle was defined as the mean of the highest HR during sitting and the lowest HR during cycling. In the arm cranking group, FLEX HR was defined as the mean HR for sitting. VO_2 during rest was calculated as the mean VO_2 of lying (respiration chamber or ventilated hood) and sitting. For periods of daytime when HR was ≤ FLEX HR, EE was calculated on the basis of this mean VO_2; when HR was above FLEX HR, EE was derived from the min-by-min recorded HR and the calibration curves obtained during cycling or during sitting and arm cranking. TEE was computed by summing the estimated EE from daytime HR (using an energy equivalent of 20.50 kJ/l O_2) and adding SMR or RMR for sleeping hours.

Physical fitness

Peak aerobic power and anaerobic power (cycling or arm cranking on Fleisch ergometer) and isokinetic strength of the knee extensors and flexors (Cybex II) was measured to determine physical fitness. Used methods are described by Berg-Emons van den *et al.* (1996b). For practical reasons, strength measurements were only performed in the second study year.

Statistical analysis

Data are expressed as mean ± SD. Comparisons between data were made using the Wilcoxon test for paired observations and the Mann-Whitney U test for unpaired observations (α = 0.05). Bivariate correlations were performed by Spearman's rank order correlation. To establish the effects of four sessions per week on aerobic and anaerobic power, data of EXP_{4x} (n = 10) were compared with CON (n = 10). The effects of two sessions per week on aerobic and anaerobic power were established by comparing the control children of the first year with themselves in the second year. Because one child of this group had to stop training because of surgery, this comparison was made on nine children (EXP_{2x} versus CON, n = 9). Also the results of the total experiment group of the second year are presented (EXP_{2xtot}, n = 17) and compared with CON (n = 10). To establish the effects of the summer holidays on fat mass, peak aerobic power and anaerobic power, results at T_0 of the second year were compared with T_9, of the first year. Such a comparison could not be made for the PA ratios, since the methods to determine the ratios differed between the two study years. For isokinetic strength measurements, only effects of two sessions per week (EXP_{2xtot}) were established; no comparisons could be made with controls. Training intensity was described as the percentage of time HR was ≥ 70% of the heart rate reserve (= difference between peak heart rate and heart rate during sleep). This measure indicates the relative exertion in the same way as the percentage of maximal oxygen uptake (Åostrand and Rodahl, 1986).

Results

There were no statistically significant differences in physical characteristics between EXP_{4x} and CON at the beginning of the study (Table 1). The training attendancy was 84% (range 78% to 88%) throughout the first year and 75% (range 54% to 94%) throughout the second year. Mean HR (beats/min) during the training sessions in the first year was 135 ± 10; in the second year 138 ± 14. Percentages of time during training spent at ≥ 70% of the heart rate reserve were respectively 49 ± 17 and 58 ± 20.

Level of daily PA

In the children who had both SMR and RMR measurements (n = 12), RMR (5.11 ± 1.22 MJ/d) was on average 16% (range −4% to +57%) higher ($P < 0.01$) than SMR (4.42 ± 0.74 MJ/d). Because of the non-systematic intra-individual differences, it was not possible to deduce SMR from RMR or vice-versa. Therefore, the calculation of PA ratios differs between children, and ratios can not be compared between groups.

Four exercise sessions per week (EXP_{4x}, Table 2) resulted after 9 months in an average increase in PA level (on a training day) versus T_0 of 0.21 (= 16%, P = 0.07). PA levels

Table 1. Characteristics of the subjects at the beginning of the study

	EXP_{4x} (n = 10)	*CON (n = 10)*
	(4 M, 6 F)	*(7 M, 3 F)*
Age (yr)	9.5 ± 1.6	8.8 ± 1.1
Height (cm)	130.7 ± 11.2	130.6 ± 9.4
Weight (kg)	33.8 ± 14.3	31.3 ± 7.7
Sum 4 skinfolds (mm)	37.4 ± 18.1	28.9 ± 9.1
Fat (%)	21.8 ± 6.1	17.9 ± 5.0
Fat mass (kg)	8.1 ± 6.2	5.7 ± 2.2
Fat-free mass (kg)	25.7 ± 8.3	25.5 ± 6.1
Body mass index (kg/m^2)	19.0 ± 4.2	18.1 ± 2.6

M, male; F, female.

Table 2. Level of daily PA (calculated as the ratio of TEE to SMR or RMR), in children who participated in a 9-month training programme (EXP_{4x} 4 times per wk; EXP_{2x} and EXP_{2xtot} 2 times per wk) and in children who had no extra exercise (CON)

	CON (n = *10)*	EXP_{4x} (n = *10)*	*CON* (n = *9)*	EXP_{2x} (n = *9)*	EXP_{2xtot} (n = *17)*
T_0[a]	1.24 ± 0.21	1.34 ± 0.25	1.26 ± 0.22	1.20 ± 0.17	1.18 ± 0.20
T_2[a]	1.34 ± 0.21	1.31 ± 0.10	1.32 ± 0.21	1.25 ± 0.08	1.18 ± 0.14
T_9[a]	1.34 ± 0.20	1.55 ± 0.18[b]	1.32 ± 0.20	1.28 ± 0.16	1.29 ± 0.20[c]

[a] T_0, base-line; T_2, after 2 months; T_9, after 9 months; [b] $P = 0.07$ versus T_0; [c] $P < 0.05$ versus T_0.

in CON showed no significant increases versus T_0. Differences in the changes in PA levels between EXP_{4x} and CON were however not statistically significant (also the area under the curve of changes from base-line did not differ significantly between EXP_{4x} and CON). EE added (above resting) by a 45 min training session was 0.28 ± 0.17 MJ (10.9 ± 6.5 kJ/kgFFM) at T_2, and 0.47 ± 0.26 MJ (16.9 ± 7.8 kJ/kgFFM) at T_9 ($P < 0.05$). The extra EE during training at T_9 represents an average increase of about 0.10 unit in the PA ratio on a training day.

During the programme with two exercise sessions per week (EXP_{2x}, Table 2), changes in PA levels were similar to the changes in PA in the year without training (CON). EE added (above resting) by a 45 min training session was 0.41 ± 0.32 MJ (12.6 ±6.7 kJ/kgFFM) at T_2 and 0.37 ± 0.23 MJ (11.1 ± 4.6 kJ/kgFFM) at T_9 (ns). The extra EE during training at T_9 represents an average increase of about 0.06 unit in the PA ratio on a training day. PA levels of EXP_{2xtot} at T_9 were increased versus T_0 with 9% ($P < 0.05$), but this was similar to the changes in CON.

Fat mass

FM (Fig. 2) increased continuously ($P < 0.05$) in CON during the study year (T_9 versus T_0: + 1.1 ± 1.6 kg), whereas FM in the experimental groups showed no changes. The difference in the change in FM from T_0 to T_2 between CON and EXP_{2x} was significant ($P < 0.05$) (between CON and EXP_{4x} $P = 0.09$; between CON and EXP_{2xtox} $P = 0.06$). There were no significant differences in the changes in FM from T_0 to T_9 between the experimental groups and CON (also the area under the curve of changes from base-line did not differ significantly between the groups). After the summer holidays (T_{12}), FM in EXP_{4x} was significantly ($P < 0.05$) higher (+ 0.7 ± 0.7 kg) compared to before the summer holidays (T_9). Changes in FM in EXP_{2xtot} were significantly different ($P < 0.05$) between children who had also trained during the first year ($n = 8$, Δ FM after 9 months is + 0.9 ± 0.9 kg) and children who had not trained during the first year ($n = 9$, Δ FM after 9 months is − 0.3 ± 0.9).

Peak aerobic power

Because there was a significant relation between fat-free mass (FFM) and peak aerobic power (Spearman correlation 0.55, $P < 0.01$), peak aerobic power is presented in watt per kg FFM (Table 3). There were no significant differences in base-line aerobic power between the experimental and control groups. After 9 months of training, peak aerobic power in EXP_{4x} had increased ($P < 0.01$) by 35% (nine children showed an increase varying from + 15% to + 376%; one child showed a decrease of 9%). During the summer

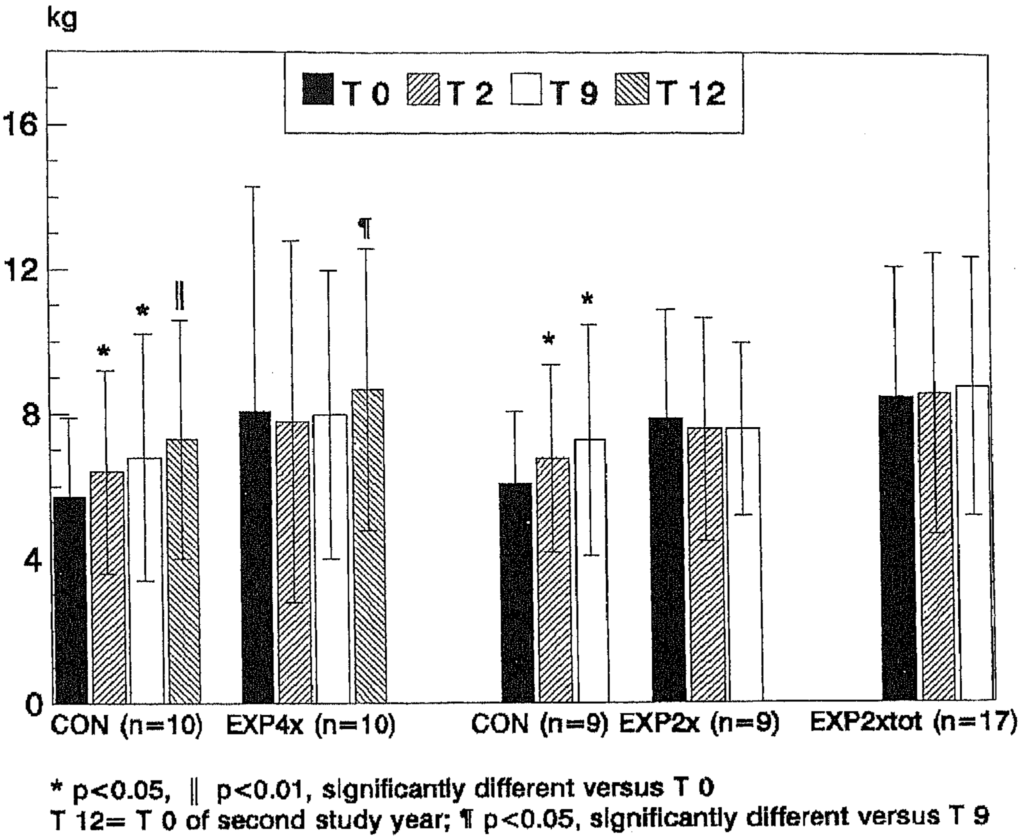


Fig. 2. Changes in fat mass (kg) in children who participated in the training programme (EXP_{4X} 4 times per wk; EXP_{2X} and EXP_{2Xtot} 2 times per wk) and in children who had no extra exercise (CON).

Table 3. Peak aerobic power (watt per kg FFM) in children who participated in a 9-month training programme (EXP_{4x} 4 times per wk; EXP_{2x} and EXP_{2xtot} 2 times per wk) and in children who had no extra exercise (CON)

	CON (n = *10)*	EXP_{4x} (n = *10)*	*CON* (n = *9)*	EXP_{2x} (n = *9)*	EXP_{2xtot} (n = *17)*
T_0[a]	1.11 ± 0.96	0.91 ± 0.83	1.03 ± 0.98	0.99 ± 0.77	0.97 ± 0.77
T_2[a]	1.01 ± 0.84	1.02 ± 0.82	0.90 ± 0.82	1.08 ± 0.86	1.03 ± 0.75
T_9[a]	1.17 ± 0.94	1.23 ± 0.80[b]	1.06 ± 0.92	1.20 ± 0.89[b]	1.16 ± 0.83[b]
T_{12}[a]	1.15 ± 0.88	1.02 ± 0.76[c]			

[a] T_0, base-line; T_2, after 2 months; T_9, after 9 months; T_{12}, after 12 months (= T_0 of second year); [b] $P < 0.01$, versus T_0; [c] $P < 0.01$, versus T_9.

holidays, peak aerobic power in EXP_{4x} decreased significantly ($P < 0.01$) by 17%. There were no significant changes in CON. Changes in peak aerobic power from T_0 to T_9 were different ($P < 0.05$) between EXP_{4x} and CON.

During the second year, EXP_{2x} showed an increase ($P < 0.01$) in peak aerobic power at T_9 of 21% (all children showed an increase varying from + 2% to + 268%), but this change was not significantly different versus CON (P = 0.17). Peak aerobic power in EXP_{2xtot} had increased (P < 0.01) at T_9 by 20% (16 children showed an increase varying from + 2% to + 268%; one child showed a decrease of 6%), not significantly different (P = 0.23) versus CON (there was also no significant difference in the area under the curve of changes from base-line between EXP_{2x} and CON and between EXP_{2xtot} and CON). Increases in EXP_{2xtot} were similar in the children who had also trained during the first year (n = 8, peak aerobic power came back to values similar to ones just before the summer holidays) and in the children who had had no training in the first year (n = 9). Absolute increases in peak aerobic power after 9 months of training were on average (over both programmes) 0.32 W/kgFFM in the cycling group and 0.18 W/kgFFM in the arm cranking group (P = 0.06). Proportionally, these effects were larger (P < 0.05) in the arm cranking group (+ 129%) than in the cycling group (+ 23%). Also effects on peak HR were different (P < 0.05) between the cycling and arm cranking group: peak HR (bts/min) in the cycling group remained constant during the training programme (175 ± 13 at T_0 and 176 ± 11 at T_9, ns), whereas peak HR in the arm cranking group tended to increase during training (125 ± 9 at T_0 and 143 ± 18 at T_9, P = 0.06).

Anaerobic power

Because there was a significant correlation between FFM and anaerobic power (Spearman correlations between FFM and PP and between FFM and MP were respectively 0.55 and 0.58 (P < 0.01)), anaerobic power is presented in watt per kg FFM (Table 4). There were no significant differences in base-line anaerobic power between the experimental and control groups. In EXP_{4x}, both PP and MP tended to be higher (P = 0.06) at T_9 compared to T_0 by respectively 15% and 11%. CON showed similar increases in PP and MP at T_9 as EXP_{4x} (11% and 13% respectively, P < 0.05). Changes in PP and MP in EXP_{2x} and EXP_{2xtot} were also not significantly different from changes in CON.

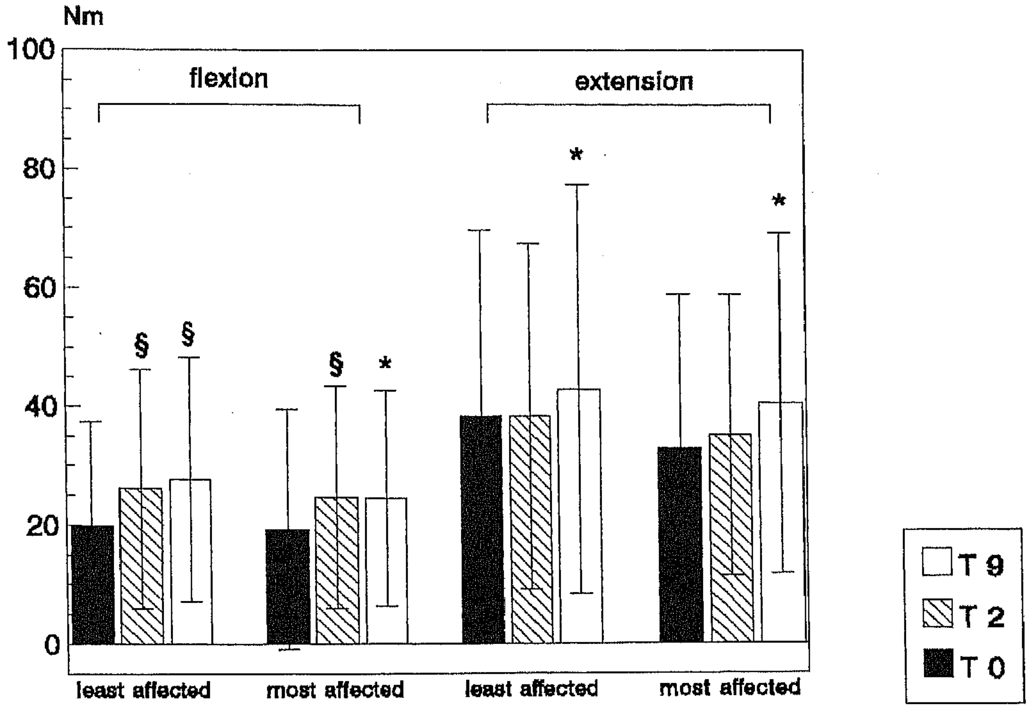
Isokinetic muscle strength

Because there were no significant correlations between anthropometric parameters (height, weight, FFM) and peak torque (PT, in Nm), nor between these parameters and the changes

Table 4. Peak anaerobic power (PP, watt per kg FFM) and mean anaerobic power (MP, watt per kg FFM) in children who participated in a 9-month training programme (EXP_{4x} 4 times per wk; EXP_{2x} and EXP_{2xtot} 2 times per wk) and in children who had no extra exercise (CON)

PP	*CON* (n = *10)*	EXP_{4x} (n = *10)*	*CON* (n = *9)*	EXP_{2x} (n = *9)*	EXP_{2xtot} (n = *17)*
T_0[a]	2.35 ± 1.75	2.16 ± 1.94	2.12 ± 1.69	2.42 ± 1.96	2.32 ± 1.89
T_2[a]	2.26 ± 1.63	2.32 ± 1.84	2.11 ± 1.65	2.33 ± 1.88	2.19 ± 1.69
T_9[a]	2.60 ± 1.86[b]	2.48 ± 1.94[c]	2.36 ± 1.81[c]	2.65 ± 1.90	2.67 ± 2.07[b]
T_{12}[a]	2.55 ± 1.89	2.41 ± 1.83			
MP	*CON* (n = *10)*	EXP_{4x} (n = *10)*	*CON* (n = *9)*	EXP_{2x} (n = *9)*	EXP_{2xtot} (n = *17)*
T_0[a]	1.92 ± 1.45	1.77 ± 1.58	1.75 ± 1.42	1.99 ± 1.63	1.89 ± 1.54
T_2[a]	1.88 ± 1.31	1.76 ± 1.40	1.77 ± 1.33	1.87 ± 1.48	1.76 ± 1.35
T_9[a]	2.17 ± 1.55[b]	1.97 ± 1.51[c]	2.03 ± 1.56[b]	2.10 ± 1.51	2.02 ± 1.53
T_{12}[a]	2.12 ± 1.60	1.90 ± 1.42			

[a] T_0, base-line; T_2, after 2 months; T_9, after 9 months; T_{12}, after 12 months (= T_0 of second year); [b] $P < 0.05$; [c] $P = 0.06$, versus T_0.



* p<0.05, § p<0.01, versus T 0

Fig. 3. Changes in flexion and extension peak torque (Nm) at 30°·s^{-1} in children who participated in a 9-month training program with 2 exercise sessions per wk (EXP_{2Xtot}, $n = 17$).

in PT during training, PT is presented in absolute units (Nm, Fig. 2). Flexion PT in the least affected leg in EXP_{2xtot} was increased at T_2 by 32% ($P < 0.01$) and at T_9 by 39% ($P < 0.01$). Flexion PT in the most affected leg was increased with 28% ($P < 0.05$) at T_2 and showed no further increases at T_9. Increases in extension PT at T_9 were 12% ($P < 0.05$) and 24% ($P < 0.05$) in respectively the least and most affected leg. There were no significant differences in the changes between children who had also trained in the first study year ($n = 8$) and children who had had no training in the first year ($n = 9$).

Discussion

In a previous study in which the HR method was compared with the doubly labelled water technique in nine children with CP (Berg-Emons van den *et al.*, 1996a), it was concluded that monitoring the HR during 3 days is preferable to obtain a close group estimate of TEE. For practical reasons, it was not possible to measure HR in the present study during more than 1 day in each measurement period, which may have reduced the accuracy of the TEE prediction. The used cycling tests and the isokinetic strength test have been found to be reliable (test–retest correlations varying from 0.71 to 0.96) in young children with spastic CP (Berg-Emons van den *et al.*, 1996b). Reliability of arm cranking tests has not been studied in children with CP.

Many children achieved during the training sessions higher heart rates than their 'peak' HR. The reason for this is that not all children were able to cycle on the ergometer and had to perform arm-cranking tests (n = 7), whereas during training these children performed various activities with a higher intensity than arm cranking (particularly cycling on their own adjusted bikes and training on a flying-saucer). In addition, some ambulant children achieved during running activities much higher heart rates than during ergometer cycling. Therefore, the calculated percentages of time spent at ≥ 70% of the heart rate reserve are an overestimation of the actual training intensity. However, considering the large improvements in aerobic power, training activities must have been performed at a reasonable intensity.

Levels of daily PA in healthy children in The Netherlands (7 to 10 years) and Northern Ireland (7 to 12 years), were found to be respectively 1.83 ± 0.23 and 1.77 ± 0.24 (Livingstone *et al.*, 1992; Berg-Emons van den *et al.*, 1995). Although different methods were used to assess PA, results of the present study indicate that the children with CP are considerably less active than healthy children, which is in agreement with measurements of daily PA with doubly labelled water in a smaller group of diplegic and tetraplegic children with CP (Berg-Emons van den *et al.*, 1995, 1996a). In comparison with representative samples of the Dutch population of the same age (Roede and van Wieringen, 1985; Berg-Emons van den *et al.*, 1996b), the children with CP are on average heavy for their height (half of the children was more than 20% heavier than the mean weight for height of Dutch children) and their test outcomes (aerobic and anaerobic power during cycling and strength of knee extensors and flexors) are on average 50 to 60% lower. Only three children had test-outcomes on the three tests within the normal range.

Effects of training on level of daily PA

Results of the present study (Table 2) indicate that four exercise sessions (45-min) per week may, in the long term, increase daily PA in children with CP, although this effect was not significantly different from changes in PA in children who had no extra training. This lack of significant difference may be due to the relatively small study population, large intra- and interindividual differences in PA, and the possibly reduced accuracy of the HR method (only one sampling day). No effects were found with two exercise sessions per week.

The increase in PA level in EXP_{4x} at T_9 can be accounted for about 50% by the direct energy cost of training and for about 50% by an increase in EE outside the training hour, in agreement with findings of Blaak *et al.* (1992) in obese boys. The increase in EE outside the training hour suggests that training may have stimulated the children with CP to be more active during daily life. CON showed an increase of 0.10 in PA level after 9 months (Table 2), but the increase was not statistically significant. However, because of the small sample size, large intra- and interindividual differences in PA and the reduced accuracy of the HR method, it cannot be excluded that children with CP increase their PA throughout a school year independent of training. Therefore, the increase in PA level outside the training hour as observed in EXP_{4x}, may have been unrelated to the training programme.

It can be concluded that training (45-min sessions four times per week) may, in the long term, increase levels of daily PA in spastic children with CP. However, although peak aerobic power in EXP_{4x} was improved considerably after 9 months (Table 3), the increase in PA, as a consequence of the training intervention, is relatively limited. After 9 months the average PA level on a training day was 1.55, but to achieve in children with CP a level of 1.8, as found in healthy children (Livingstone *et al.*, 1992; Berg-Emons van den *et al.*, 1995), as much as 2.5 hours of aerobic training are needed daily (assuming an energy level comparable to what was achieved at T_9 in the first year). This is not feasible, which means that sports programmes can only partly restore the deficit in PA in children with CP. Therefore, children with CP will never have equal opportunities for growth and development when compared with healthy peers.

Effects of training on fat mass

The present study implies that, although changes in FM were not significantly different between experimental and control groups in the long term (may be due to small study population, large intra- and interindividual differences in FM), physical training may prevent deterioration in body composition in children with CP. Two 45-min sessions per week seem to be sufficient in this respect. The finding that the control children showed significant increases in FM (Fig. 2) is in agreement with the study of Dresen (1983). According to Saris *et al.* (1985), the mean gain in FM in healthy Dutch children is about 0.5 kg per year at 8–10 years of age. The mean gain in the control group was considerably higher than these reference values, namely 1.5 kg per year.

Effects on peak aerobic power

Results of the present study indicate that aerobic training with a frequency of four sessions per week, has pronounced effects on peak aerobic power in children with CP (increase is on average 35%), in agreement with previous studies (Lundberg *et al.*, 1967; Berg 1970; Bar-Or *et al.*, 1976; Wormgoor and Gierlings, 1989; Fernandez and Pitetti, 1993). Peak aerobic power in CON did not increase during the school year, indicating that habitual activity patterns in children with CP, including gymnastic lessons, are not sufficient to induce improvements in aerobic power. Two sessions per week resulted in average increases in peak aerobic power of 21% (EXP_{2x}) and 20% (EXP_{2xtot}), but these changes were not significantly different versus CON.

The relatively low peak HR (both in cycling and arm cranking groups) indicates that peak aerobic performance in the children with CP was attained at low levels of cardiorespiratory stress. Apparently, aerobic exercise testing in these children by means of cycle ergometry and arm cranking is restricted by non-cardiorespiratory factors. During training, peak HR remained constant in the cycling group, whereas peak HR in the arm cranking group tended to increase with on average 14 bts/min. These results suggest that in the cycling group (in general less severely handicapped), the increase in peak aerobic power is caused by the oxygen effect (change in oxygen uptake at the same HR; Berg and Bjure, 1970), and in the arm cranking group (in general severely affected) by probably a combination of oxygen effect and muscle effect (difference in peak HR before and after training, due to improved muscle performance, Berg and Bjure, 1970). This finding is in agreement with the study of Berg (1970) in severely handicapped children with CP.

Effects on anaerobic power

Although training activities were predominantly aerobic, effects on anaerobic performance were also studied, because it may be hypothesized that aerobic training of children with low activity levels might also induce increases in anaerobic power. However, results of the study do not support this hypothesis: increases in anaerobic power during the study years were similar in the experimental and control groups, indicating that they are independent of training. The increases in anaerobic power in the children with CP are in agreement with findings of Bar-Or (1983) and Falgairette *et al.* (1991) in healthy children and are probably due to qualitative changes in muscles with increasing age. From the results obtained on anaerobic power, the importance of also including a control group in training studies in growing children becomes apparent.

Effects on isokinetic muscle strength

Results of the study suggest that, although no comparisons could be made with controls, aerobic training may increase isokinetic muscles strength of the knee extensors and flexors in children with CP. Possible explanations for this increase in muscle strength may be increases in muscle mass, synchronization of motor unit recruitment, and a decrease in cocontraction of agonist and antagonist muscles. Significant improvements in torque of 59% were also found by McCubbin and Shasby (1985) in children with CP and adolescents, but their training programme consisted of isokinetic exercise (elbow extension).

General conclusion

Although training has only a limited effect on restoring the deficit in PA in children with CP, regular physical exercise is important in young children with spastic CP because it may prevent deterioration in body composition. Furthermore, aerobic training is effective in eliciting higher peak aerobic power and seems to increase isokinetic muscle strength in children with CP. No effects of aerobic training are found on anaerobic power. Most pronounced effects of training on aerobic power were achieved with four sessions (45 min) per week. Because of strenuous therapy programmes during school time, especially in severely affected children, this relatively high frequency of training during school hours may not be feasible. Participation in organized sports activities outside the rehabilitation centre is therefore recommendable in addition to training activities at school. However, at the moment, the possibilities for handicapped children to be intensively active outside the rehabilitation centre are limited. Therefore, much effort has to be invested in creating out-of-school training programmes for handicapped children.

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